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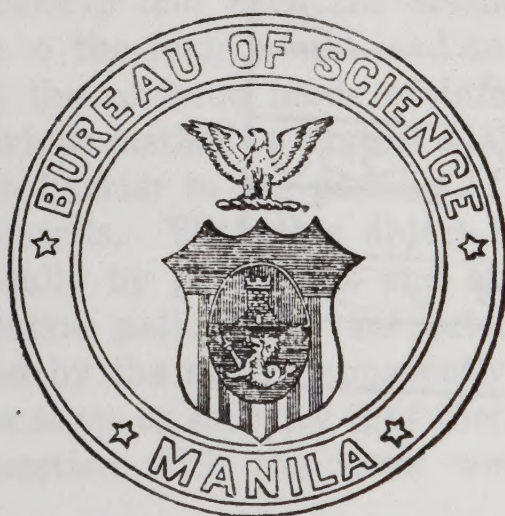
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STUDIES ON PNEUMONIC PLAGUE AND PLAGUE IMMUNIZATION.

XII. SOME EXPERIMENTS TO DETERMINE THE EFFICACY OF VARIOUS MASKS FOR PROTECTION AGAINST PNEUMONIC PLAGUE.

By M. A. BARBER AND OSCAR TEAGUE.

(From the Biological Laboratory, Bureau of Science, Manila, P. I.)

During the epidemic of pneumonic plague which raged in Manchuria during the winter of 1910 to 1911, it was believed and, toward the close of the epidemic, was experimentally demonstrated, by Strong and Teague, that sputum in the form of invisible droplets containing viable plague bacilli was frequently suspended in the air near the coughing pneumonic-plague patients. A Petri dish, containing solidified agar-culture-medium, held for a minute or two before the mouth of a patient and closed after a single cough did in some instances on incubation show numerous colonies of plague bacilli, although no visible particles of sputum had been thrown against it.¹ There was every reason to believe that even the smallest number of these bacilli inhaled into the lung would lead to infection and that this was, in fact, the common mode of infection in pneumonic plague. The obvious method to protect against such infection was to interpose a barrier to the passage of these droplets into the mouth and nostrils. With this object in view, masks were worn quite generally by physicians and attendants when in the presence of plague patients or suspected cases. That protection was afforded by the masks apparently went unquestioned and, without the sense of security that their use gave, the mental strain in connection with the work would have been almost unbearable.

The total number of deaths that occurred among physicians,

¹ Report of the International Plague Conference held at Mukden, April, 1911. Manila (1912), 83. See also II, p. 137 of this report.

nurses, attendants, and inspectors during the recent epidemic of pneumonic plague in Manchuria will never be known. The following death roll at Fuchiatien, the Chinese city near Harbin, shows that the total must have been extremely high.

List of deaths of antiplague staff at Fuchiatien.²

Doctors	1 out of	20
Students	1 out of	29
Native practitioners	4 out of	9
Police inspectors	2 out of	31
Police	30 out of	688
Sanitary police	11 out of	206
Mounted police	5 out of	80
Firemen	5 out of	20
Coolies	102 out of	550
Cooks	4 out of	60
Ambulance parties	69 out of	150
Soldiers	63 out of	1,100
Total		297 out of 2,943

In South Manchuria the plague sanitary corps suffered a loss of 122 persons among whom were 1 Japanese, 1 English, and 40 Chinese physicians. This represents 2.66 per cent of the total plague mortality in the districts concerned.³

The presumption is that all of the members of the sanitary corps wore masks. The masks were, however, not worn constantly nor were they always properly adjusted; coolies were often seen with the masks hanging around their necks instead of being over their mouths. Hence the high death rate of the sanitary staff can not be regarded as proof of the inefficiency of masks.

In Mukden the mask which was almost universally employed consisted of a pad of absorbent cotton about 16 by 12 centimeters and about 1.5 centimeters thick; this was wrapped in gauze, the ends of which were tied at the back of the head. (See Plate V, fig. I. B.) A many-tailed bandage (see Plate V, fig. I. A) composed of three layers of gauze with holes for the eyes was tied around the entire head and served to press the mask firmly against the face and to keep it snugly in place for hours at a time. When first put on, this mask was decidedly uncomfortable, but after a few minutes one became somewhat accustomed to it and could wear it for two or three hours at a time. There was, however, always an intense feeling of

² *Ibid.*, p. 242.

³ *Ibid.*, p. 244.

relief on removing it. We shall designate this type of mask in the discussion to follow as the "Mukden mask."⁴

The following experiments were undertaken with the idea of determining whether this Mukden mask is, in fact, an efficient barrier against the passage of plague bacilli into the lungs and, also, whether or not other types of masks are more efficient.

At the International Plague Conference held in Mukden in April, 1911, Broquet, the French delegate, demonstrated a mask "copied from those used by doctors in the epidemic of the fourteenth century as shown in old books."⁵ It consisted of a hood of light canvas or khaki cloth, covering the entire head and drawn in at the neck. In front was a window of mica. No experiments had been performed to test the efficacy of this mask. We shall refer to this type of mask hereafter as the "Broquet mask." It was not used during the recent epidemic of pneumonic plague in Manchuria with the exception of a few times by Broquet himself.

Our preliminary tests indicated that a hood of heavy Canton flannel with a nap was more effective in holding back *Bacillus prodigiosus* than hoods of lighter cloth such as the one demonstrated by Broquet. Instead of mica for the window, we used sheet celloidon such as one sees in the storm curtains of automobiles. The hood was made narrow at the neck so that it would spread out over the shoulders and could be drawn in and tied snugly around the neck. Comparative experiments were made with this mask and the Mukden mask; the subjects wearing the two masks were forced to breathe air containing *Bacillus prodigiosus* simultaneously for the same length of time.

Bacillus prodigiosus was selected for the experiments as being entirely harmless and easily recognizable on account of its pigment production. An ordinary throat atomizer was used for making the spray, but with the idea of getting smaller droplets the rubber bulb was removed and a stronger airblast was obtained by using an automobile pump.

Special precautions were taken to avoid accidental contamination with *B. prodigiosus* on removing the mask. (See Plate V, fig. 2.) The subject was clothed in an operating gown and, in the case of the Mukden mask, his head was covered with a cloth and the eyes protected by automobile goggles. The spraying was generally done in a small, single-roomed stable which

⁴ We were informed that this mask was extensively used in Harbin before its introduction into Mukden.

⁵ Report of the International Plague Conference, p. 303.

was boarded up on all sides to keep out the light and to avoid, to a certain extent, currents of air. The gowns, goggles, and head-cloths were removed after the subjects had left the stable and before they entered the laboratory building. One of the authors attended to the spraying and exposure of the subjects, the other endeavored to keep himself and his laboratory room free from *B. prodigiosus* and made the necessary plate-cultures in order to determine the result of the test. At first the saliva, taken before and after the spraying, was smeared over agar plates, but later it was found that small pieces of moistened cotton, placed in the nostrils and before the mouth (underneath the Mukden mask), rendered the test much more delicate.

Agar plates were exposed during the course of the experiment in order to obtain an indication of the *living* prodigiosus bacilli that were in the air around the mask at that time.

The following protocols, selected from a long series of such experiments, demonstrate the general mode of procedure and the results obtained.

PROTOCOL NO. 1. (EXPERIMENT NOS. 97 AND 98.)

Two laboratory boys⁶ served as subjects. Control plates were made as follows: A quantity of saliva was expectorated into a plate containing solidified agar, distributed by means of a sterile cotton plug, and a small

⁶The first experiment was performed upon ourselves to demonstrate the harmlessness of the procedure. Then several of our colleagues and about 8 different laboratory boys served as subjects in these experiments. Yet, owing to the large number of experiments that were done, it was found necessary to use the same laboratory boys repeatedly as subjects. However, a period of at least a week was allowed to elapse before a boy was again called upon to serve, and then smears were made from nostrils and saliva to determine whether by any chance *Bacillus prodigiosus* was present. These tests proved to be in every case negative. In order to gain some idea of the length of time that *Bacillus prodigiosus* can persist in the mouth, one of us rinsed his mouth with a suspension of prodigiosus (one slant in 10 cubic centimeters of salt solution) and gargled some of the same suspension. Plates inoculated with his saliva at intervals gave the following results:

Saliva after three-fourths hour	Plate No. 1: Overgrown with prodigiosus.
Saliva after 3½ hours	{ Plate No. 1: Overgrown with prodigiosus.
	{ Plate No. 1: Overgrown with prodigiosus.
Saliva after 5½ hours	Plate No. 1: Overgrown with prodigiosus.
Saliva after 16 hours	{ Plate No. 1: 20 colonies of prodigiosus.
	{ Plate No. 2: 15 colonies of prodigiosus.
Saliva after 19½ hours	{ Plate No. 1: No colonies of prodigiosus.
	{ Plate No. 2: No colonies of prodigiosus.

Two meals were taken during the course of this experiment.

portion spread thinly over a second agar plate. Both plates were preserved for growth and examination. At the same time the nostrils were swabbed with a small pledget of sterile cotton moistened with salt solution and this rubbed over solidified agar. (In no case was *B. prodigiosus* obtained from the nostrils or saliva in these controls taken before spraying.)

The boys were clothed with operating gowns.

Boy No. 1 wore a Mukden mask consisting of two and one-half layers of Johnson and Johnson absorbent cotton. Thin layers of this cotton in Petri dishes were steamed in an Arnold sterilizer and then placed in the ice box so that water would condense upon the cotton and inside of the Petri dishes. A portion of the cotton thus moistened was placed in approximately the center of the mask between the layers of the cotton, so that when the mask was in place it lay before the mouth and nostrils. Small bits of the moist cotton were placed within the nostrils and a larger piece before the mouth and nostrils. This latter piece was held in place by the mask. Small pieces of dry absorbent cotton were placed on each side of the nose and then the Mukden mask was tied in place. Automobile goggles were worn over the eyes. The exposed portion of the head above the mask was covered with a cloth.

Boy No. 2 wore a Broquet mask of heavy Canton flannel cloth. This hood had been used in a number of previous experiments after each of which it had been disinfected in lysol solution and placed in the sun to dry. Small bits of the steamed moist cotton were placed loosely within the nostrils, and as in the preceding instance a larger piece of the same cotton was placed over the mouth and nostrils. This was held in place by a strip of gauze which was tied at the back of the head. A straw hat was placed on the boy's head, and the mask was then put on and tied in snugly around the neck. (See Plate V, fig. 2.)

The two boys, thus masked, were taken into a stable with the walls boarded up to keep out the light and to prevent currents of air. A suspension of *prodigiosus* bacilli in 0.5 per cent sodium chloride solution (1 agar slant in about 40 cubic centimeters) was sprayed by means of a throat atomizer connected with an automobile pump. The spray was directed alternately toward one mask and then the other for a period of three minutes. The boys were then brought back to the laboratory. But the gowns, goggles, and head-cloths were removed before they entered the laboratory building which was only a few meters away. This was done in order to prevent a possible contamination of the test culture plates with *prodigiosus* bacilli which might have become scattered in the air while the masks were being removed. (The gowns and cloths were sterilized in an autoclave at 120°C. before they were used in the next experiment.)

The subjects then proceeded to the door of the laboratory room where the masks were removed and cultures made as follows:

The cotton taken from before the mouth, that from the nostrils, and, in case of the Mukden mask, that from the interior of the mask were transferred by sterile forceps to separate Petri dishes containing solidified agar, and rubbed over the surface of the agar. Each mass of cotton was then transferred to a second Petri dish well wet with salt solution and rubbed over the second plate and left on the surface of the media.

The cotton was wet in order to afford conditions for growth to any *B. prodigiosus* which might otherwise have remained in the dry center of the cotton. (In a few cases the wet cotton mass alone, after twenty-four hours, showed the red color indicative of the growth of *B. prodigiosus*.) All plates were left in the dark at room temperature (25° to 30°C.), protected by glass jars.

The result of all the cultures, read two days later, was as follows:

Boy No. 1. Mukden mask.

Saliva taken before exposure	{ Plate No. 1: <i>Prodigiosus</i> absent.
	{ Plate No. 2: <i>Prodigiosus</i> absent.
Cotton from nostrils before exposure	{ Plate No. 1: <i>Prodigiosus</i> absent.
	{ Plate No. 2: <i>Prodigiosus</i> absent.
Cotton from nostrils after exposure	{ Plate No. 1: <i>Prodigiosus</i> present.
	{ Plate No. 2: <i>Prodigiosus</i> present.
Cotton before mouth after exposure	{ Plate No. 1: <i>Prodigiosus</i> present.
	{ Plate No. 2: <i>Prodigiosus</i> present.
Cotton within the mask after exposure	{ Plate No. 1: <i>Prodigiosus</i> present.
	{ Plate No. 2: <i>Prodigiosus</i> present.

Boy No. 2. Canton flannel Broquet mask.

Saliva taken before exposure	{ Plate No. 1: <i>Prodigiosus</i> absent.
	{ Plate No. 2: <i>Prodigiosus</i> absent.
Cotton from nostrils before exposure	{ Plate No. 1: <i>Prodigiosus</i> absent.
	{ Plate No. 2: <i>Prodigiosus</i> absent.
Cotton before mouth after exposure	{ Plate No. 1: <i>Prodigiosus</i> present.
	{ Plate No. 2: <i>Prodigiosus</i> present.
Cotton from nostrils after exposure	{ Plate No. 1: <i>Prodigiosus</i> present.
	{ Plate No. 2: <i>Prodigiosus</i> present.

A plate exposed to the air of the laboratory room, while the above plates were being prepared, showed no red colonies.

DISCUSSION OF PROTOCOL NO. 1.

This experiment shows that neither the Mukden mask nor the heavy Canton flannel Broquet mask is able to hold back completely *prodigiosus* bacilli when they are sprayed in large numbers continuously for a period of three minutes about the heads of the subjects. As this Broquet mask is the most efficient of all the masks with which we have experimented, it follows that none of our masks can withstand this test. The fact that the moist cotton from the center of the Mukden mask contained many *prodigiosus* bacilli shows that some of the *prodigiosus* bacilli passed directly through the mask; or, in other words, that the inefficiency of this mask is not due solely to the fact that the bacilli pass around the edges of the cotton pad or through the free spaces at the sides of the nose which were,

perhaps, only imperfectly plugged with cotton.⁷ In this experiment the masks are subjected to a much more severe test than would occur in practice; nevertheless, it presents conclusive evidence, we believe, that these masks do not offer absolute protection against infection with pneumonic plague.

PROTOCOL NO. 2. (EXPERIMENTS NOS. 69 AND 70.)

February 3. A fresh culture of *B. prodigiosus* upon slanted agar was suspended in 0.5 per cent sodium chloride solution and about one-half of this suspension was sprayed through an atomizer by means of an automobile pump. The spray was directed toward all parts of a small single-roomed stable with the walls boarded up to keep out the light and, to a certain extent, the currents of air. Three minutes after the spraying had been discontinued, two subjects, one wearing our Canton flannel Broquet mask and the other a "Mukden mask" were taken into the room and allowed to remain for ten minutes. The temperature of the stable measured 28° 5 C. The weather was overcast and there had been a drizzling rain of short duration about one hour before the experiment began.

Number of living B. prodigiosus in the air.

Time after spraying.		Number of <i>prodigiosus</i> colonies.
Subjects exposed.	$\frac{1}{2}$ to 3 minutes	Innumerable.
	3 to 6 $\frac{1}{2}$ minutes	11,400
	6 $\frac{1}{2}$ to 9 minutes	1,416
	9 to 12 minutes	472
	12 to 23 minutes	63

Subject No. 1. Canton flannel Broquet mask.

Saliva taken before exposure	{ Plate No. 1: <i>Prodigiosus</i> absent.
	{ Plate No. 1: <i>Prodigiosus</i> absent.
Cotton from nostrils before exposure	{ Plate No. 1: <i>Prodigiosus</i> absent.
	{ Plate No. 2: <i>Prodigiosus</i> absent.
Cotton from nostrils after exposure	{ Plate No. 1: <i>Prodigiosus</i> absent.
	{ Plate No. 2: <i>Prodigiosus</i> absent.
Cotton before mouth after exposure	{ Plate No. 1: <i>Prodigiosus</i> absent.
	{ Plate No. 2: <i>Prodigiosus</i> absent.

⁷ In another experiment we obtained further evidence that bacteria may pass directly through the cotton pad of the Mukden mask. Layers of cotton as thick as the Mukden mask, sufficiently wide to cover the entire face and overlapping at the back of the head, were held in place by a many-tailed bandage, no openings in the cotton or bandage being made for the eyes. The remaining portion of the subject's head and his neck were then bandaged with layers of cotton of the same thickness and a suspension of *prodigiosus* bacilli was sprayed about his head for a period of seven minutes. The bacilli were recovered from the cotton immediately before his mouth and from his saliva.

Subject No. 2. Mukden mask.

Saliva taken before exposure	{ Plate No. 1: Prodigiosus absent.
	{ Plate No. 2: Prodigiosus absent.
Cotton from nostrils before exposure	{ Plate No. 1: Prodigiosus absent.
	{ Plate No. 2: Prodigiosus absent.
Cotton from nostrils after exposure	{ Plate No. 1: Prodigiosus <i>present</i> .
	{ Plate No. 2: Prodigiosus <i>present</i> .
Cotton before mouth after exposure	{ Plate No. 1: Prodigiosus <i>present</i> .
	{ Plate No. 1: Prodigiosus <i>present</i> .
Cotton within the mask after exposure	{ Plate No. 1: Prodigiosus absent.
	{ Plate No. 2: Prodigiosus absent.

DISCUSSION OF PROTOCOL NO. 2.

Living prodigiosus bacilli were very numerous at the beginning of the test, but decreased very rapidly during the ten minutes that the subjects were exposed. This must be regarded also as a very severe test, though by no means so severe as the preceding one. The Broquet mask withstood the tests, while the Mukden mask failed to hold back all the prodigiosus bacilli. This experiment, therefore, demonstrates clearly the superiority of the Broquet mask over the Mukden mask.

PROTOCOL NO. 3. (EXPERIMENTS NOS. 67 AND 68.)

February 1, 1912. Spraying as the preceding experiment. The two masked subjects were taken into the stable six minutes after the spraying had been discontinued and allowed to remain ten minutes. Hot, sunshiny day. Temperature in the stable 29°C.

Number of living prodigiosus bacilli in the air.

Time after spraying.		Number of prodigiosus colonies.
Subjects exposed.	1 to 3 minutes	6,000
	3 to 6 minutes	2,760
	6 to 9 minutes	280
	9 to 12 minutes	127
	12 to 15 minutes	29
	15 to 30 minutes	1

Subject No. 1. Mukden mask.

Saliva taken before exposure	{ Plate No. 1: Prodigiosus absent.
	{ Plate No. 2: Prodigiosus absent.
Cotton from nostrils before exposure	{ Plate No. 1: Prodigiosus absent.
	{ Plate No. 2: Prodigiosus absent.
Cotton from nostrils after exposure	{ Plate No. 1: Prodigiosus absent.
	{ Plate No. 2: Prodigiosus absent.
Cotton before mouth after exposure	{ Plate No. 1: Prodigiosus absent.
	{ Plate No. 2: Prodigiosus <i>present</i> .
	(Cotton red and 32 colonies.)
Cotton within the mask after exposure	{ Plate No. 1: Prodigiosus absent.
	{ Plate No. 2: Prodigiosus absent.

Subject No. 2. Canton flannel Broquet mask.

Saliva taken before exposure	{ Plate No. 1: Prodigiosus absent.
	{ Plate No. 2: Prodigiosus absent.
Cotton from nostrils before exposure	{ Plate No. 1: Prodigiosus absent.
	{ Plate No. 2: Prodigiosus absent.
Cotton before mouth after exposure	{ Plate No. 1: Prodigiosus absent.
	{ Plate No. 2: Prodigiosus absent.
Cotton from nostrils after exposure	{ Plate No. 1: Prodigiosus absent.
	{ Plate No. 2: Prodigiosus absent.

DISCUSSION OF PROTOCOL NO. 3.

This test was an extremely light one. A Petri dish exposed during the first three minutes that the masked subjects were in the room developed only 280 prodigiosus colonies and another, during the last three minutes, only 29 colonies. In spite of the small number of living prodigiosus bacilli that were in the air, the Mukden mask failed to hold back all of them. We are inclined to believe that this test is even a less severe one than that to which the masks were subjected during the recent plague epidemic in Manchuria, as the coughing patients in the crowded wards must have been throwing out hundreds of fine droplets almost continuously and, on account of the low temperature, the plague bacilli in these droplets must have remained suspended in the air in a viable condition for a considerable period of time. Since we have found repeatedly in tests which were not severe that the Mukden mask allowed bacilli to pass, we are forced to the conclusion that the sense of security felt by those who wore this mask in the Manchurian epidemic was not justified.

PROTOCOL NO. 4.

This experiment was carried out in a cold-storage room measuring about 2.5 by 3 meters at a temperature of 12°C. A 24-hour agar-culture of prodigiosus was suspended in about 40 cubic centimeters of 0.5 per cent sodium chloride solution and filtered twice through cotton. A portion of this suspension was sprayed by means of a throat atomizer connected by rubber tubing with a two-cylinder force-pump such as is used in filling automobile tires. The spraying was continued for a period of two minutes, the spray being directed toward all portions of the room. The pump was then removed and the door of the cold room quickly closed. A period of two hours was allowed to elapse, and then the three masked boys were hurried into the room and the door was closed behind them. They remained ten minutes in the room. During this time each held in his hand an open Petri dish containing solidified agar and closed it immediately after leaving the cold room.

Boy No. 1 wore a Mukden mask, boy No. 2 our Canton flannel Broquet mask. The usual measures against accidental contamination with *B. prodigiosus* were adopted. Boy No. 3 wore a mask of wet gauze. Strips of

gauze were boiled and while still warm were squeezed out and applied loosely over the lower portion of the face from the eyes to below the chin. The gauze was not in layers but was placed irregularly as in surgical dressings which are intended to absorb pus. A many-tailed bandage with holes for the eyes, such as is used with the Mukden mask, pressed the moist gauze firmly against the face and held it snugly in place. This mask was about five or six centimeters thick over the mouth and became thinner toward the edges. Goggles were worn by this boy also and the top of his head was covered with a cloth reaching down to the mask.

Boy No. 1. Mukden mask.

Saliva taken before exposure	{ Plate No. 1: Prodigiosus absent. Plate No. 2: Prodigiosus absent.
Cotton from nostrils before exposure	Prodigiosus absent.
Cotton within mask after exposure	{ Plate No. 1: Prodigiosus present. Plate No. 2: Prodigiosus present.
Cotton before mouth after exposure	{ Plate No. 1: Prodigiosus present. Plate No. 2: Prodigiosus present.
Cotton from nostrils after exposure	{ Plate No. 1: Prodigiosus present. Plate No. 2: Prodigiosus present.
Plate held by boy during exposure	4,420 prodigiosus colonies.

Boy No. 2. Broquet mask.

Saliva taken before exposure	{ Plate No. 1: Prodigiosus absent. Plate No. 2: Prodigiosus absent.
Cotton from nostrils before exposure	Prodigiosus absent.
Cotton before mouth after exposure	{ Plate No. 1: Prodigiosus absent. Plate No. 2: Prodigiosus absent.
Cotton from nostrils after exposure	{ Plate No. 1: Prodigiosus absent. Plate No. 2: Prodigiosus absent.
Plate held by boy during exposure	4,000 prodigiosus colonies.

Boy No. 3. Mask of wet gauze.

Saliva taken before exposure	{ Plate No. 1: Prodigiosus absent. Plate No. 2: Prodigiosus absent.
Cotton from nostrils before exposure	Prodigiosus absent.
Cotton before mouth after exposure	{ Plate No. 1: Prodigiosus present. Plate No. 2: Prodigiosus present.
Cotton from nostrils after exposure	{ Plate No. 1: Prodigiosus present. Plate No. 2: Prodigiosus present.
Plate held by boy during exposure	4,485 prodigiosus colonies.

DISCUSSION OF PROTOCOL NO. 4.

In spite of the long interval (two hours) which elapsed between the spraying and the exposure of the subjects, this test must be regarded as a very severe one, for the plates show that numerous living prodigiosus bacilli still remained suspended in

the air at the time of the exposure. Furthermore, the number of living bacilli in the air in the cold room remains practically constant during the ten minutes of the test, while, as we have seen, in the warm stable there is a rapid decrease. This experiment shows again the superiority of our Broquet mask over the Mukden mask. It also proves that prodigious bacilli may pass directly through the cotton pad of the Mukden mask, for a piece of moist cotton placed near the center of the pad contained prodigious bacilli after the test. The mask of wet gauze also failed to hold back all the bacilli and is hence inferior to our Broquet mask. The experiment does not afford any evidence as to the relative efficiency of the Mukden mask and the mask of moist gauze.

PROTOCOL NO. 5.

March 1, 1912. The mouth of one of us was rinsed with sterile salt solution and then about 10 cubic centimeters of saliva were collected in a sterile test tube. One slant of a fresh prodigious culture was suspended in this saliva. The resulting suspension was thoroughly shaken and then taken a little at a time into the mouth and made into a spray by being blown between the lips. The spraying was done in a cold storage room at 9°C. The room was then kept closed for one hour, when the three masked subjects were quickly taken in and the door closed behind them. They remained inside ten minutes, each subject holding during that time an open Petri dish of solidified agar.

The masks were removed and cultures made as in the preceding experiment.

Number of living prodigious bacilli in the air.

	Number of prodigious colonies.
Plate held by subject No. 1	2,340
Plate held by subject No. 2	2,405
Plate held by subject No. 3	3,120

Subject No. 1. Mukden mask.

Saliva taken before exposure	{ Plate No. 1: Prodigious absent.
	{ Plate No. 2: Prodigious absent.
Cotton from nostrils before exposure	{ Plate No. 1: Prodigious absent.
Cotton from nostrils after exposure	{ Plate No. 1: Prodigious <i>present</i> .
	{ Plate No. 2: Prodigious <i>present</i> .
Cotton before mouth after exposure	{ Plate No. 1: Prodigious <i>present</i> .
	{ Plate No. 2: Prodigious <i>present</i> .
Cotton within the mask after exposure	{ Plate No. 1: Prodigious <i>present</i> .
	{ Plate No. 2: Prodigious <i>present</i> .
Saliva taken after exposure	{ Plate No. 1: Prodigious absent.
	{ Plate No. 2: Prodigious absent.

Subject No. 2. Canton flannel Broquet mask.

Saliva taken before exposure	{ Plate No. 1: Prodigiosus absent. Plate No. 2: Prodigiosus absent.
Cotton from nostrils before exposure	{ Plate No. 1: Prodigiosus absent. Plate No. 2: Prodigiosus absent.
Cotton from nostrils after exposure	{ Plate No. 1: Prodigiosus absent. Plate No. 2: Prodigiosus absent.
Cotton before mouth after exposure	{ Plate No. 1: Prodigiosus absent. Plate No. 2: Prodigiosus absent.
Saliva taken after exposure	{ Plate No. 1: Prodigiosus absent. Plate No. 2: Prodigiosus absent.

Subject No. 3. Mask of wet gauze.

Saliva taken before exposure	{ Plate No. 1: Prodigiosus absent. Plate No. 2: Prodigiosus absent.
Cotton from nostrils before exposure	{ Plate No. 1: Prodigiosus absent. Plate No. 2: Prodigiosus absent.
Cotton from nostrils after exposure	{ Plate No. 1: Prodigiosus absent. Plate No. 2: Prodigiosus absent.
Cotton before mouth after exposure	{ Plate No. 1: Prodigiosus <i>present</i> . Plate No. 2: Prodigiosus <i>present</i> .
Saliva taken after exposure	{ Plate No. 1: Prodigiosus absent. Plate No. 2: Prodigiosus absent.

DISCUSSION OF PROTOCOL NO. 5.

This experiment was designed to approximate more nearly to the conditions that occurred in Manchuria. It seemed possible that the viscid sputum of pneumonic plague might form larger droplets than the salt solution of our experiments and on that account be unable to pass through the masks. Preliminary tests were made by taking prodigiosus bacilli into the mouth and then holding Petri dishes containing solidified agar immediately before the mouth while talking or coughing. It was found that under these conditions prodigiosus bacilli were emitted in too small numbers and too inconstantly for the method to be satisfactory in testing our masks. Swabbing the vocal cords with the bacilli might have given satisfactory results, but this was not tried. Instead of this, it was decided to blow saliva containing prodigiosus bacilli between the lips thus converting it into a spray. The droplets of saliva produced in this way apparently passed through the masks as readily as the salt solution droplets from the atomizer. This experiment furnishes strong evidence that droplets of sputum from pneumonic-plague patients may be able to pass through the Mukden mask.

General discussion.—The protocols which have been cited could be supplemented by numerous others⁸ giving similar results.

While these experiments furnish evidence that fine droplets of sputum of patients suffering from pneumonic plague may pass through the mask that was so widely used in Manchuria, yet they do not at all indicate that this mask was entirely without value. Obviously, the mask would hold back gross visible particles of sputum which are sometimes thrown out in coughing. Moreover in our experiments, when prodigious bacilli were recovered from the nostrils, it is probable that in the same test without the mask far greater numbers would have entered; in other words, it seems probable that great numbers of bacteria, that otherwise would have entered the nose and mouth, remain on the surface of the mask and in its substance.

Hence we believe that masks should be worn by those attending pneumonic-plague patients, but that they should not be regarded as affording absolute protection against infection; bearing this in mind, even when masked, one should remain in the near vicinity of the patient only so long as is necessary for the work in question.

CONCLUSIONS.

(1) The "Mukden mask" in general use during the epidemic of pneumonic plague in Manchuria, during the winter of 1910 to 1911, does not prevent the passage into the mouth and nostrils of *B. prodigiousus* when contained in small droplets sprayed

⁸ The Mukden mask was used in 42 tests and was found to hold back the prodigiousus bacilli in only 6 of these and to allow them to pass in 36 instances. Of the 6 tests in which the bacilli failed to penetrate the mask, three were preliminary experiments to determine whether a satisfactory spray was produced in talking or coughing after rinsing the mouth with a suspension of prodigiousus bacilli; plates exposed during the experiment showed less than 20 colonies each and the method was therefore abandoned. In two others of these 6 tests the exposed plates showed only 15 and 200 colonies respectively. Finally, in the last of these 6 tests, the subject drew the cotton from before his mouth and nose into his mouth where it became saturated with saliva and plates were not made from the cotton within the nostrils.

In some of the tests in which the prodigiousus bacilli passed through the Mukden mask, the exposed plates contained only a few colonies, indicating that the test was much less severe than those in the protocols recorded above.

Our Canton flannel Broquet mask was employed in 17 different experiments. It held back all the prodigiousus bacilli in 10 of these and allowed some of them to pass in 7.

around the mask. This mask consists of a pad of absorbent cotton held over the mouth and nose by a many-tailed gauze bandage.

(2) A hood of heavy Canton flannel cloth, covering the entire head and tied in snugly at the neck, withstands much severer tests than does the Mukden mask. It does not, however, offer an absolute barrier to the passage of prodigious bacilli into the mouth and nostrils of the subject. This mask, with a window in front, is not more inconvenient nor more uncomfortable than the Mukden mask.

(3) It is shown that the inefficiency of the Mukden mask is not due solely to the fact that the mask fails to conform to the configuration of the face but that the bacteria may pass directly through the mask; for a piece of moist cotton placed in the center of the mask was found after the test to contain prodigious bacilli.

(4) It is believed that, although masks hold back many bacteria that would otherwise pass into the mouth and nostrils, nevertheless their use during the recent epidemic of pneumonic plague in Manchuria lent a *false* sense of security which may have led to the taking of unnecessary risks. We believe that these experiments fully justify the conclusion that masks such as were used in that epidemic do not offer an absolute protection against pneumonic plague.

STUDIES ON PNEUMONIC PLAGUE AND PLAGUE IMMUNIZATION. ILLUSTRATIONS.

PLATE I.

Pneumonic plague hospital, Mukden.

- FIG. 1. Side view.
2. Rear view.

PLATE II.

- FIG. 1. American laboratory within courtyard of plague hospital, Mukden.
2. Room in which necropsies were performed in Mukden.

PLATE III.

- FIG. 1. Ward with attendants in plague hospital, Mukden.
2. Some of the nurses and attendants outside of plague ward.

PLATE IV.

Uniform adopted for protection from infection when in contact with pneumonic-plague cases.

PLATE V.

Masks for protection against pneumonic plague.

- FIG. 1. The Mukden mask.

- A. The many-tailed bandage to hold the pad securely in place.
B. The cotton pad wrapped in gauze.
2. Two subjects wearing the modified Broquet mask and the Mukden mask, respectively, ready for exposure to the sprayed bacilli.

PLATE VI.

The tarbagan (*Arctomys bobac* Schreb.). (Photograph by Dr. Wu.)

PLATE VII.

- FIG. 1. Lung of guinea pig which died of advanced plague infection after being exposed to air in which plague bacilli were suspended by means of spraying.
2. Lung of monkey which died of pneumonic-plague infection from inhalation; lobular pneumonia.
3. Lung of monkey which died of pneumonic-plague infection from inhalation, showing progression of lesions; lobular and lobar pneumonia.

PLATE VIII.

Human lung in pneumonic plague; marked lobar pneumonia, showing deep hyperæmia of bronchi.

PLATE IX.

Human lung in pneumonic plague, showing more well-marked areas of lobular pneumonia and pleural exudate.

PLATE X.

Human lung, pneumonic plague, showing gray hepatization and fibrinous pleurisy.

PLATE XI.

Human throat, larynx, and trachea in pneumonic plague. Marked hyperæmia of the larynx and trachea; the tonsils not swollen; marked hyperplasia of an incised lymphatic gland to the right of the trachea and of a small more hæmorrhagic gland at the base of the trachea.

PLATE XII.

FIG. 1. Lung of dog with pneumonic plague.

2. Liver of tarbagan (*Arctomys bobac* Schreb.), showing chronic plague infection.

PLATE XIII.

Microscopical section of human lung, showing particularly congestion of the alveoli filled with plague bacilli. (Drawn from magnification of 150 diameters.)

PLATE XIV.

Microscopical section of human lung, showing particularly alveoli filled with plague bacilli. (Drawn from magnification of 780 diameters.)

PLATE XV.

Microscopical section of human lung in advanced stage of pneumonia, showing bacilli in great masses about blood vessels. (Drawn from magnification of 780 diameters.)

PLATE XVI.

Microscopical section of human lung in stage of hepatization with absence of fibrin. Section stained for fibrin by Weigert's method. (Drawn from magnification of 330 diameters.)

PLATE XVII.

Microscopical section of human lung in pneumonic plague, showing character of alveolar exudate. (Drawn from magnification of 330 diameters.)

PLATE XVIII.

Microscopical section of human tonsil, pneumonic plague, showing congestion. (Drawn from magnification of 150 diameters.)

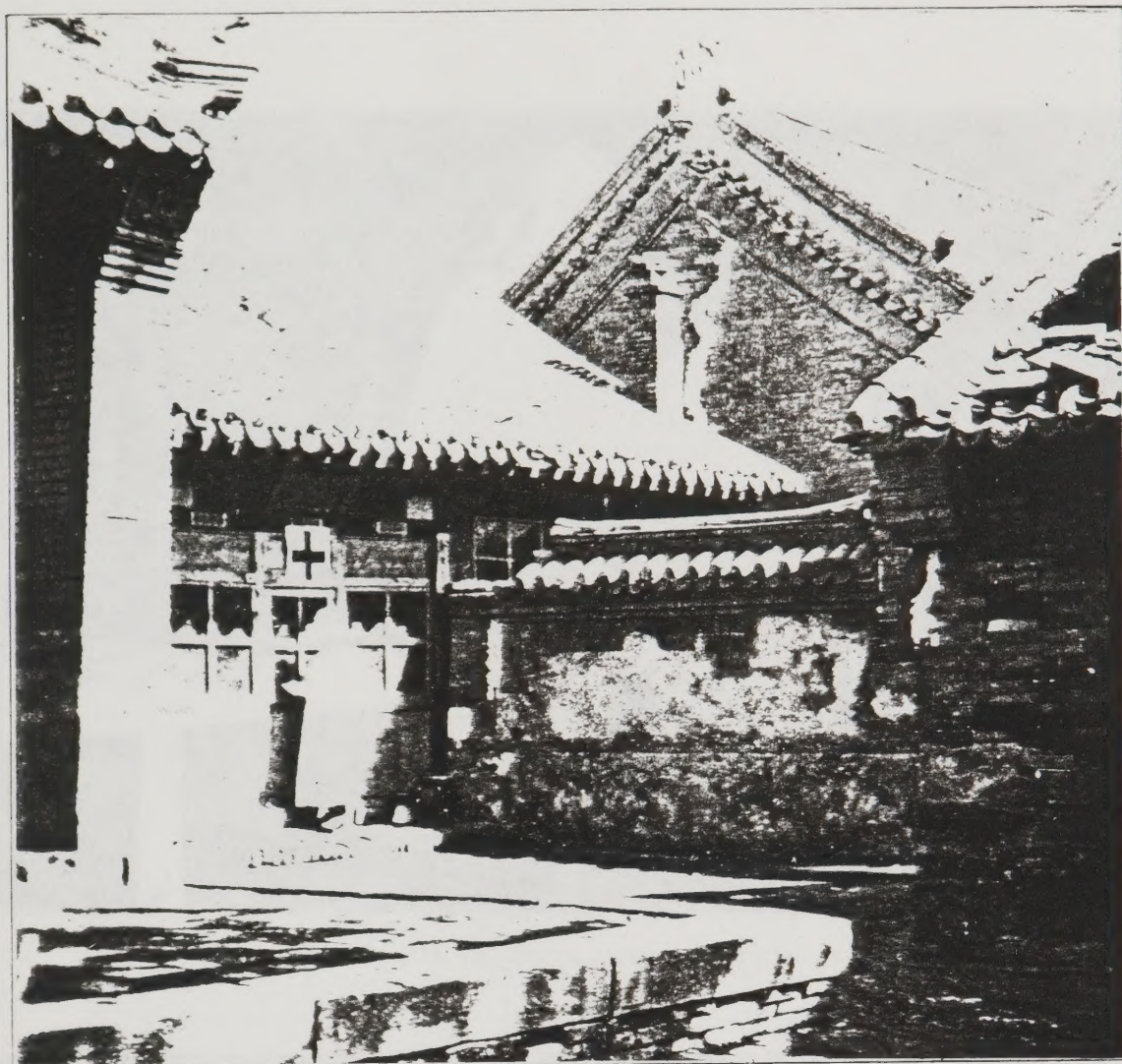


Fig. 1. American laboratory within courtyard of plague hospital. Mukden.

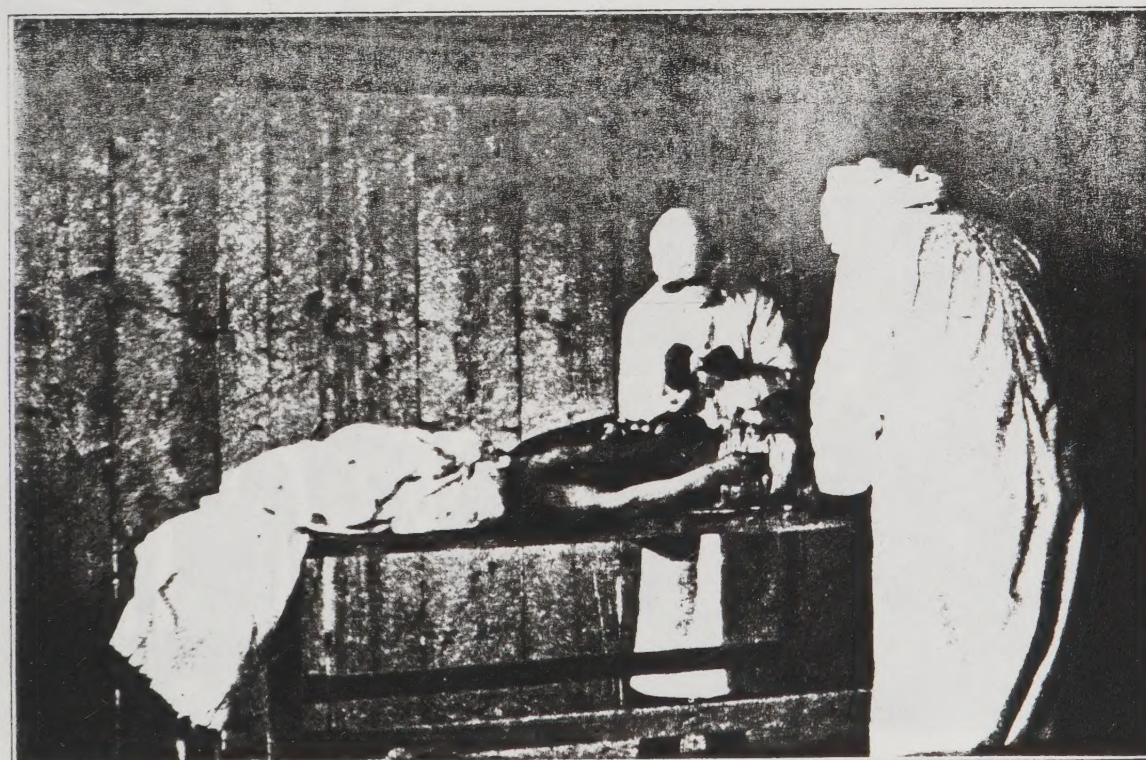


Fig. 2. Room in which necropsies were performed in Mukden.

PLATE II.

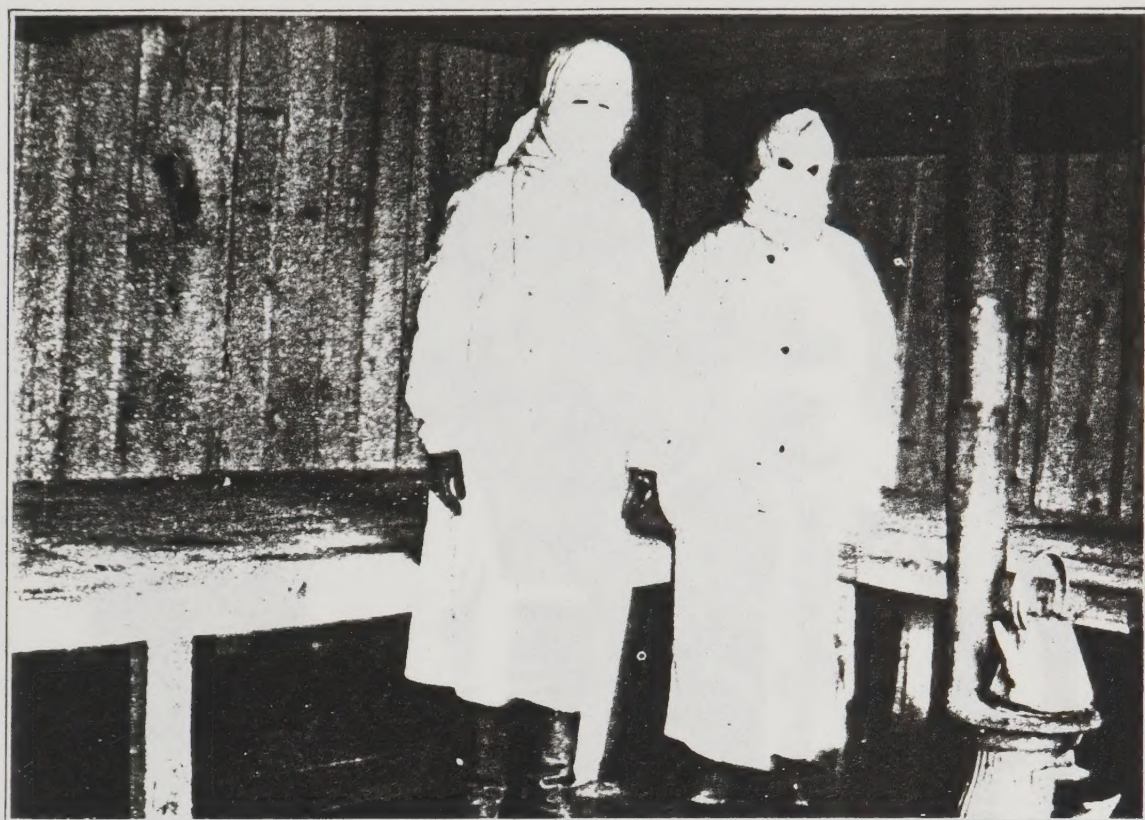


Fig. 1. Ward with attendants in plague hospital. Mukden.



Fig. 2. Some of the nurses and attendants outside of plague ward.

PLATE III.



PLATE IV. UNIFORM ADOPTED FOR PROTECTION FROM INFECTION WHEN IN
CONTACT WITH PNEUMONIC-PLAGUE CASES.



Fig. 1. Side view.



Fig. 2. Rear view.

PLATE I. PNEUMONIC-PLAGUE HOSPITAL, MUKDEN.

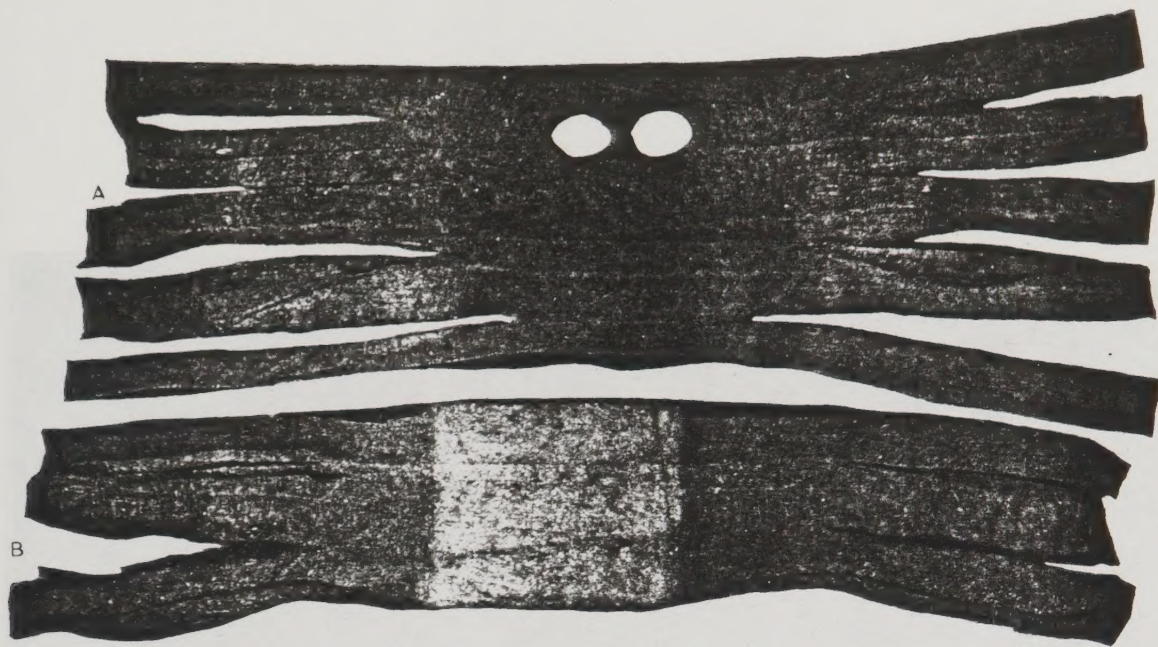


Fig. 1. The Mukden mask. A. The many-tailed bandage to hold the pad securely in place.
B. The cotton pad wrapped in gauze.



Fig. 2. Two subjects wearing the modified Broquet mask and the Mukden mask, respectively,
ready for exposure to the sprayed bacilli.



PLATE VI. The TARBAGAN (*Arctomys bobac* Schreb.).



Fig. 1. Lung of guinea pig which died of advanced plague infection, after being exposed to air in which plague bacilli were suspended by means of spraying.



Fig. 2. Lung of monkey which died of pneumonic-plague infection from inhalation; lobular pneumonia.

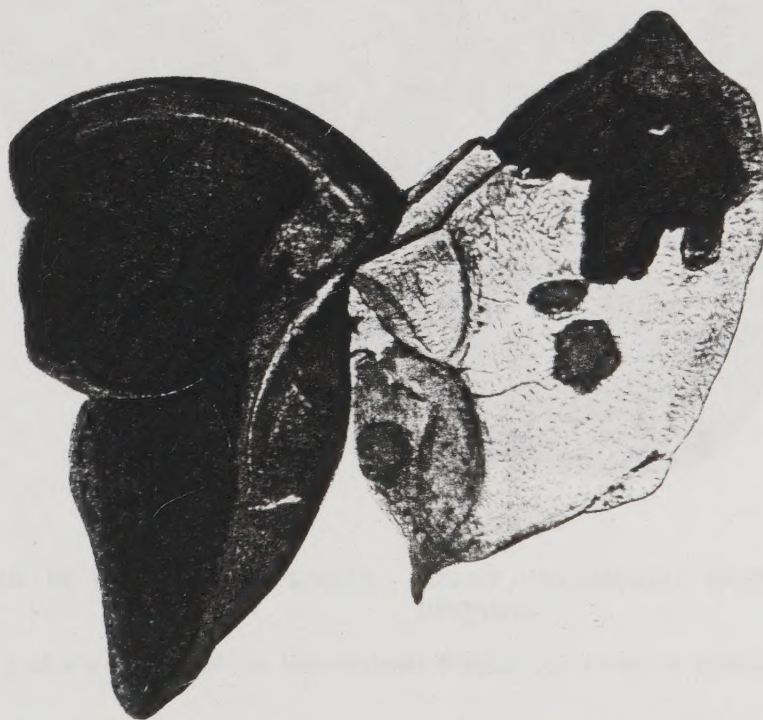


Fig. 3. Lung of monkey which died of pneumonic-plague infection from inhalation, showing progression of lesions; lobular and lobar pneumonia.



PLATE VIII.

PLATE I. LUNG IN PNEUMONIC PLAGUE. LOBAR PNEUMONIA; SHOWING DEEP HYPERÆMIA OF BRONCHI.

Plate I of the Report of the International Plague conference is reproduced here as Plate VIII.



PLATE IX. HUMAN LUNG IN PNEUMONIC PLAGUE, SHOWING MORE WELL-MARKED AREAS OF LOBULAR PNEUMONIA AND PLEURAL EXUDATE.

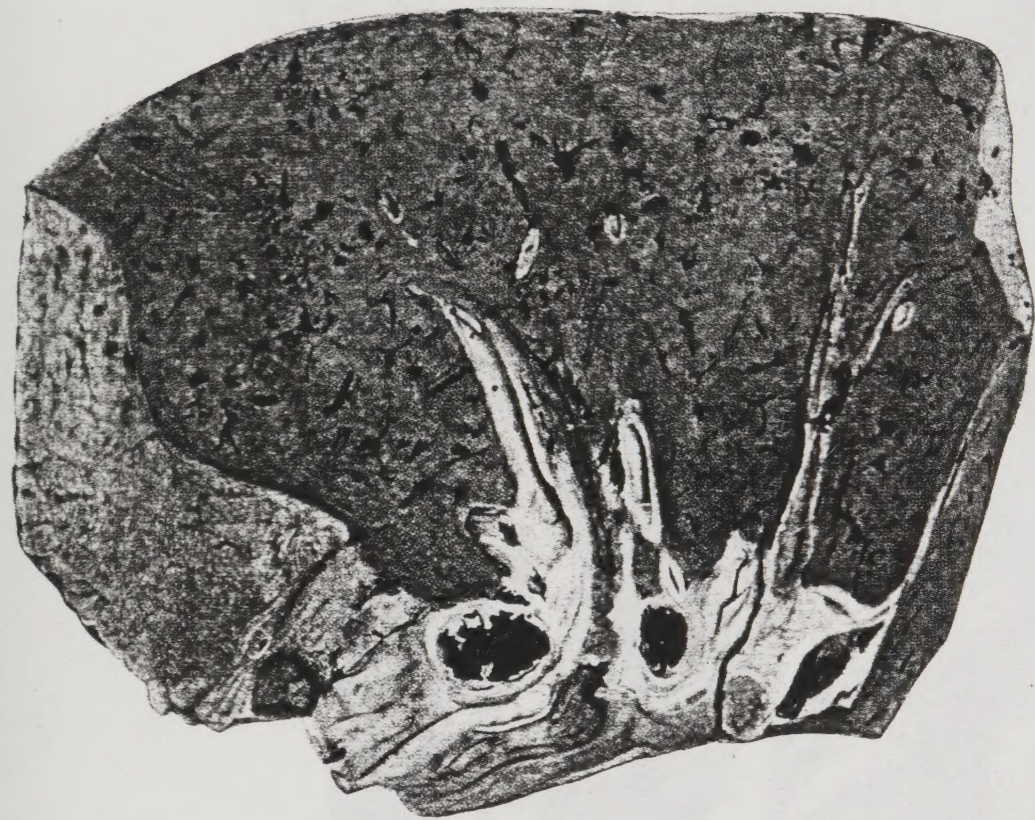


PLATE X. HUMAN LUNG, PNEUMONIC PLAGUE, SHOWING GRAY HEPATIZATION AND FIBRINOUS PLEURISY.



PLATE XI.

PLATE II. THROAT, LARYNX, AND TRACHEA IN PNEUMONIC PLAGUE. MARKED HYPERÆMIA OF THE LARYNX AND TRACHEA; TONSIL NOT SWOLLEN. MARKED HYPERPLASIA OF AN INCISED LYMPHATIC GLAND TO THE RIGHT OF THE TRACHEA, AND OF A SMALL MORE HÆMORRHAGIC LYMPHATIC GLAND AT THE BASE OF THE TRACHEA.

Plate II of the Report of the International Plague Conference is reproduced here as Plate XI.



Fig. 1. Lung of dog with pneumonic plague.



Fig. 2. Liver of tarbagan (*Arctomys bobac* Schreb.), showing chronic plague infection.



PLATE XIII. MICROSCOPICAL SECTION OF HUMAN LUNG, SHOWING PARTICULARLY CONGESTION OF THE ALVEOLI FILLED WITH PLAGUE BACILLI.

(Drawn from magnification of 150 diameters.)

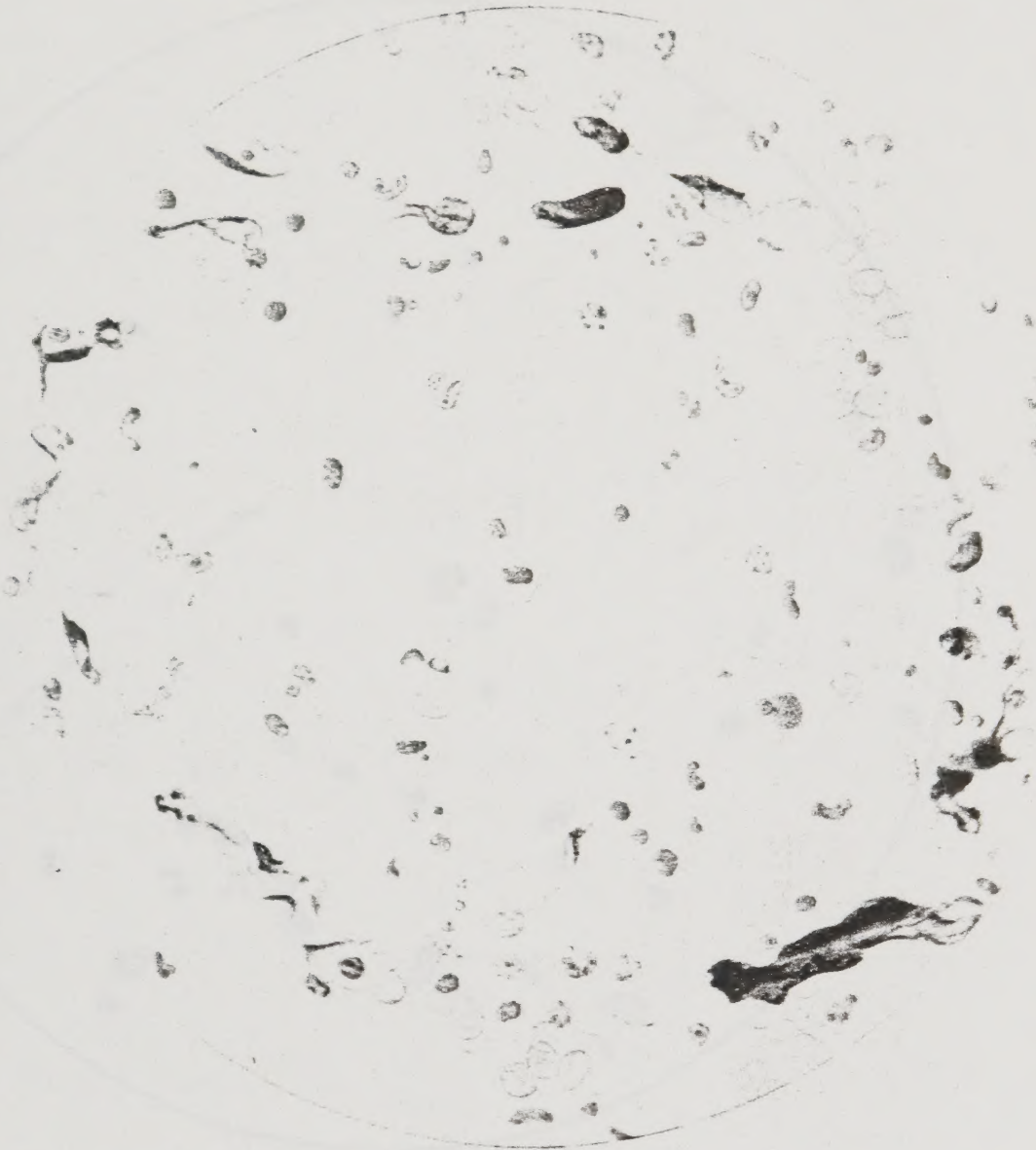


PLATE XIV. MICROSCOPICAL SECTION OF HUMAN LUNG, SHOWING PARTICULARLY ALVEOLI FILLED WITH PLAGUE BACILLI.

(Drawn from magnification of 780 diameters.)

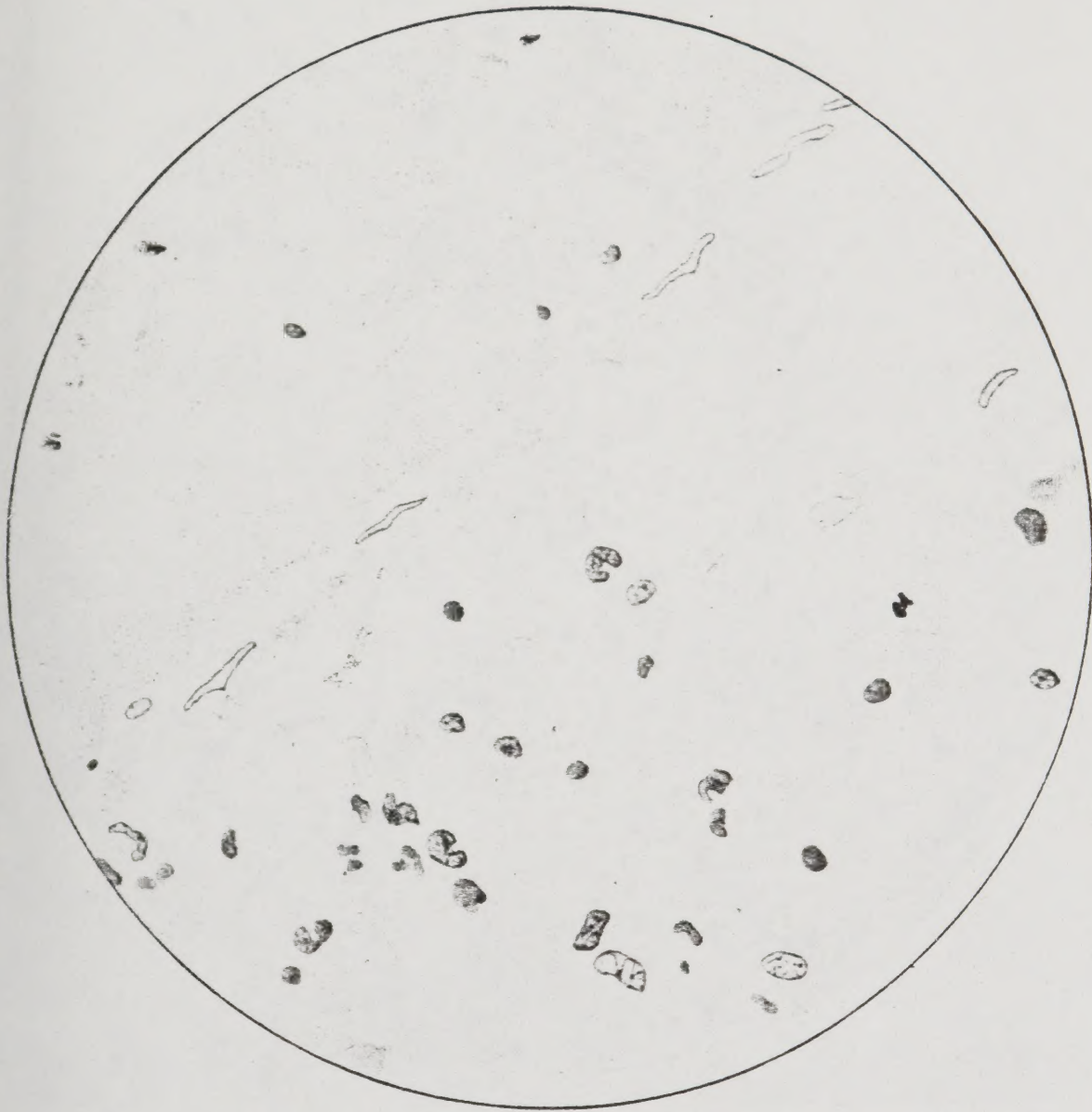


PLATE XV. MICROSCOPICAL SECTION OF HUMAN LUNG IN ADVANCED STAGE OF PNEUMONIA, SHOWING BACILLI IN GREAT MASSES ABOUT BLOOD VESSELS.

(Drawn from magnification of 780 diameters.)

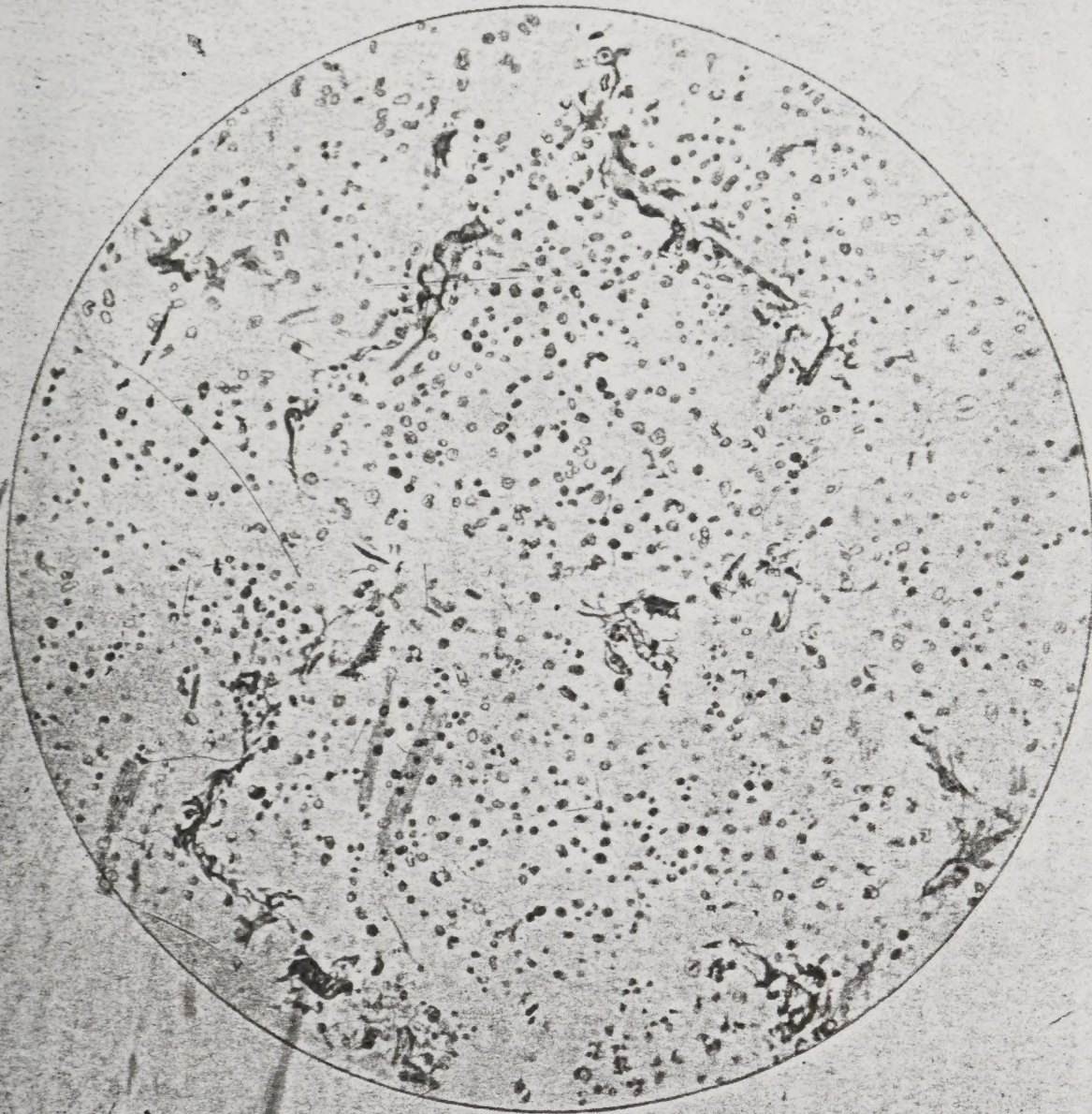


PLATE XVI. MICROSCOPICAL SECTION OF HUMAN LUNG IN STAGE OF HEPATIZATION
WITH ABSENCE OF FIBRIN. SECTION STAINED FOR FIBRIN
BY WEIGERT'S METHOD.

(Drawn from magnification of 330 diameters.)

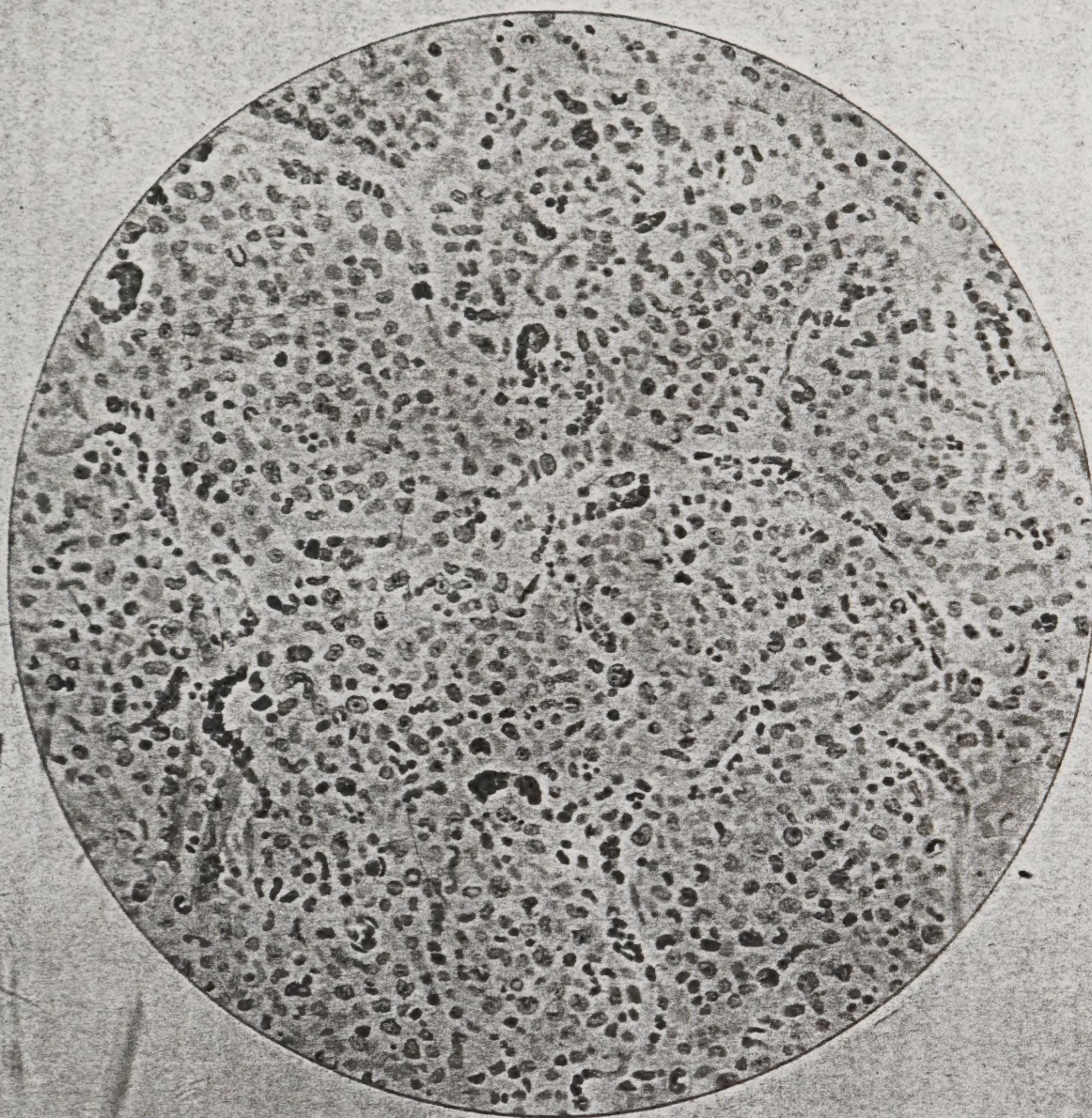


PLATE XVII. MICROSCOPICAL SECTION OF HUMAN LUNG IN PNEUMONIC PLAGUE,
SHOWING CHARACTER OF ALVEOLAR EXUDATE.

(Drawn from magnification of 330 diameters.)



PLATE XVIII. MICROSCOPICAL SECTION OF HUMAN TONSIL, PNEUMONIC PLAGUE,
SHOWING CONGESTION.

(Drawn from magnification of 150 diameters.)



Figure 1. Aerial view of the study area. The area is divided into four quadrants by a north-south line and an east-west line. The area is labeled with the letters A, B, C, and D in the corners. The area is also labeled with the numbers 1, 2, 3, and 4 in the center of each quadrant. The area is also labeled with the letters E, F, G, and H in the center of each quadrant. The area is also labeled with the numbers 1, 2, 3, and 4 in the center of each quadrant.